WORLD CATALOG OF OIL SPILL RESPONSE PRODUCTS

1999/2000

A COMPLETE LISTING OF

- BOOMS
- SKIMMERS
- SORBENTS
- PUMPS
- OIL/WATER SEPARATORS
- BEACH CLEANERS
- DISPERSANT APPLICATION EQUIPMENT
- TEMPORARY STORAGE DEVICES

HVIDE Marine took delivery of three new "Double Eagle" tankers in late 1998. These double-hull tankers were constructed by Newport News Shipbuilding and fully comply with OPA-90.

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Appendix C

OIL SPILL ENCOUNTER RATE FOR CONTINGENCY PLANNING

1.0 INTRODUCTION

Spill response professionals are looking for high spill recovery capacity. However, a desired recovery capacity can only be achieved if the spilled oil can be collected fast enough for the skimming and pumping systems to operate at their rated capacity. After oil has spread over a broad area, recovery capacity depends on the rate at which the skimming system encounters the oil slick. For advancing skimmers, encounter rate depends on skimming speed, sweep width, and the amount of oil available, in this case measured in terms of slick thickness. This Appendix shows how to compute oil spill encounter rate for advancing skimmers and how this information can be used at spill sites or to develop contingency plans.

2.0 DEFINITIONS

Here are the terms that are basic to describing the performance of advancing skimmers.

Sweep Width is the width of the entrance to the skimmer or the skimmer plus the associated containment boom used to collect oil, measured in either feet or meters.

Sweep Rate is the area the skimming system covers per unit of time measured in square nautical miles per hour (NM^2/hr). This produces small numbers but since hydrographic charts are scaled in nautical miles and boats measure their speed in knots, this is the most practical alternative.

Spill Encounter Rate uses a measured or estimated slick thickness to determine the amount of oil available to the skimmer measured in barrels per hour or cubic meters per hour (BBL/hr or m^3/hr).

There are some other terms peculiar to this discussion that will be defined as we go along, but this provides the essentials to continue.

Achieving a high encounter rate has some physical limitations that are difficult to overcome. Some advancing skimmers operating alone can successfully recover oil at a fairly high speed of advance, probably in the range of 2 to 5 knots; however, their Sweep Width at these speeds is very small. Sweep Width can be increased appreciably by operating skimmers with containment boom deployed in a sweeping mode, but in this configuration effective sweep speed is generally reduced to less than a knot. The trade-off, then, becomes one of either sweeping at less than a knot with a large boom configuration or sweeping at a higher speed with an independent skimmer that has a very narrow sweep width.

In most cases, oil is collected for recovery using containment boom, so the skimming speed or **S**peed **O**f **A**dvance (SOA) is limited to about 0.75 to 1 knot. Since the SOA is fixed, Sweep Rate can only be increased by increasing Sweep Width with greater lengths of boom. Containment boom towed in a "U" configuration is typically about 600 feet (180 m) long which results in a Sweep Width of about 200 feet (60 m). In some cases the boom length may be 1,500 to 2,000 feet (460 to 600 m) giving a Sweep Width of 500 to 670 feet (150 to 200 m); however, very often boom length must be restricted because of problems of maneuverability of the skimming system. Increasing Sweep Rate by increasing Sweep Width with more boom has practical limitations so the contingency planner should be careful not to plan on using a Sweep Width that is beyond the system's capability to operate effectively. More specifically, the planner should not show a high level of capability with long boom configurations that cannot be handled effectively in the local environment.

Having addressed these problems, we are now ready to discuss oil Spill Encounter Rate and how it can be used.

3.0 COMPUTING SPILL ENCOUNTER RATE

Computing oil Spill Encounter Rate is one of the few numerical means of evaluating advancing skimming systems for contingency plans. These computations provide the contingency planner with the following information:

- How fast the spill area is being covered
- How fast oil is being recovered based on measured or estimated slick thickness

- If the published skimmer pumping (or skimming) rate is adequate to handle the recovered oil
- The total area covered in a standard work period
- The total volume of oil recovered during a standard work period
- The storage capacity required to meet recovery requirements
- The oil/water separator capacity needed to reduce water content to be consistent with available storage capacity.

All of the functions described above, and several more, can be performed using a contingency planning Work Sheet and the graph in Figure C-1 to compute Sweep Rate and Spill Encounter Rate. A sample Work Sheet is shown in Table C-1. Each item on the Work Sheet is described in the paragraphs that follow. The Work Sheet contains data from an example that will show how the Sheet can be used to solve a typical spill response problem. The numbered paragraphs below correspond to the rows in the Work Sheet. Table C-2 provides a blank work sheet that can be used as a guide to solve specific contingency planning problems.

3.1 Work Sheet Entries

1) Skimmer Type & Model - type skimmer and manufacturer's model designation

2) Skimming Speed, knots - should generally be that reported by the equipment manufacturer; however, in some cases, when it appears that the reported skimming speed is inflated, speed should be reduced on the data sheet. In most cases, advancing skimmers that use containment boom to collect oil cannot skim effectively at speeds higher than 0.75 - 1 knot. Systems using short lengths of boom deployed in a "V" at a very shallow angle to the direction of movement may be able to skim at 1.5 to 2 knots; however, long lengths of boom frequently form a "U" rather than a "V" and lose oil by entrainment outside the "mouth" of the skimmer at speeds higher than 1 knot. For a system using containment boom, any reported skimming speed greater than 2 knots is suspect.

Some skimmers can operate independently, without using containment boom to collect oil, at speeds of 3 to 6 knots. The advantage is that they are able to skim effectively at higher speeds of advance than skimming systems using booms, but the disadvantage is that their sweep width is narrow. In many cases this is an acceptable trade-off because the skimmer operating alone is much more maneuverable. Further, oil spilled on open water may move into wind rows, so that sweeping at relatively high speed along the narrow wind rows can be the most effective mode of operation.

3) Sweep Width, ft (m) - the published Sweep Width of the skimming system. For a skimmer operating alone, it is the width of the mouth of the skimmer. For systems employing containment boom, use the published Sweep Width of the system or assume Sweep Width to be one-third the total length of the containment boom used in the system. Spill Encounter Rate is almost always increased by increasing Sweep Width; however, there are practical limitations as to how much containment boom can be used with a recovery system.

4) Sweep Rate, NM^2/hr - the result of multiplying 2) (Skimming Speed) and 3) (Sweep Width) in feet divided by 6,076 or the Sweep Width in meters by 1,852 to convert to nautical miles. (The Sweep Rate can be determined by inspection from Figure C-1; enter with the Sweep Width and go vertically to the speed of advance and read the Sweep Rate in NM^2/hr on the ordinate.) Sweep Rate is a basic planning number for spill response and contingency planning. If a petroleum facility has a harbor area or other water surface area that is threatened by a spill, this number can be used to determine how long it will take to sweep that area with existing skimmers, or conversely, how many skimming units will be required to sweep out the area in a fixed period of time.

5) Spill Encounter Rate for a specified slick thickness, BBL/hr (m^3/hr) - the result of 4) (Sweep Rate) multiplied by the estimated slick thickness in mm times a conversion factor of 21,570 to convert the result to barrels/hour or times 3,430 to obtain the result in cubic meters/hour. (The Spill Encounter Rate can also be determined from Figure C-1; go horizontally across the graph at the proper Sweep Rate to the slick thickness, then down to determine the Spill Encounter Rate.) Spill Encounter Rate can be used in three ways: 1) to estimate how long it may take to recover a spill of a specified size, 2) to determine if the Published Pumping Rate of the skimming system is adequate to handle the anticipated spill, and 3) to determine if the recovered oil storage space is adequate to support the expected spill recovery rate. For planning purposes, the Spill Encounter Rate can be

determined for a 1 mm slick; the user can then obtain values for a variety of local conditions by multiplying this encounter rate by the slick thickness estimated in a contingency plan scenario. For more precise results, compute spill encounter rate rather than use graphs. Equations used to make this computation are summarized below.

Spill Encounter Rate (BBL/hr) = (Sweep Width [ft]/6076) X Skimming Speed (knots) X Slick Thickness (mm) X 21,570

Spill Encounter Rate (m^3/hr = (Sweep Width [m]/1,852) X Skimming Speed (knots) X Slick Thickness (mm) X 3,430

6) Area Covered in NM^2 for various work periods - the result of multiplying item 4) (Sweep Rate) and various standard work periods such as 4 hours, 8 hours, 10 hours can be used to tally up the expected skimmer performance during these periods. The standard work period may be different for various recovery systems based on operator experience, time of the year, skimmer off loading times, and/or the frequency with which the recovery system storage must be evacuated.

7) Oil Volume recovered for a specified slick thickness, BBL (m^3) - the result of multiplying item 5) (Spill Encounter Rate) and various standard work periods such as 4 hours, 8 hours, and 10 hours.

8) Storage Volume Required for various work periods, BBL (m^3) - either the total volume recovered, oil plus water, or just the oil fraction (Row 7) if oil/water separation is possible. Without separation, Storage Volume Required can be computed by dividing the Oil Volume Recovered in item 7) by the percent oil recovered.

9) Pumps - shows system pump type. This can be used to estimate pumping performance with various viscosity products if the data are not provided by the manufacturer.

10) Spill Encounter Rate for a 1 mm Slick - In BBL/hr this is the Sweep Rate in NM^2/hr multiplied by the constant 21,570, or in m^3/hr, it is the Sweep Rate multiplied by 3,430. This result can be multiplied by the measured or estimated slick thickness in mm to determine Spill Encounter Rate for a particular spill situation.

11) Published Pumping Rate, BBL/hr (m^3/hr) - the pumping rate reported by the equipment manufacturer. The user should consult the manufacturer's pump curves because pumping rate will vary with oil viscosity. The resulting number should be checked against the expected recovery rate to determine if the skimmer pump is adequate.

12) Slick thickness corresponding to the maximum pumping rate, mm - shows the maximum slick thickness the system pump can handle based on the reported Sweep Rate. It can be computed by dividing published pump capacity by Spill Encounter Rate for a 1 mm slick. An approximate result can also be obtained using Figure C-1. Assume Spill Encounter Rate is the Published Pumping Rate, then go vertically to the computed Sweep Rate. These two lines will intersect at the slick thickness that corresponds to the maximum pumping rate. Slick thickness corresponding to the maximum pumping rate is shown on skimmers data sheets for all advancing skimmers.

13) Oil Viscosity - can be helpful in estimating oil recovery efficiency for skimmers that have a known or tested performance in various oils.

14) Waves, ft (m) - wave height can be used to estimate skimmer performance

15) Percent oil recovered - the approximate percent oil that can be expected in the recovered mixture. This number can be used to estimate recovered product storage requirements and oil/water separation requirements. ("Throughput efficiency" is the percent oil recovered of the oil encountered. If this number is known, it should also be used to compute storage and oil/water separation requirements.)

3.2 Sample Spill Encounter Rate Computation

The following example shows how oil Spill Encounter Rate can be used in contingency planning. In the United States, the Oil Pollution Act of 1990 (OPA-90) defines a Maximum Most Probable Discharge of 2,500 BBL (400 m^3) and specifies that vessel owners and operators must have spill response resources capable of arriving at the spill in 12 hours in high volume port areas and the Great Lakes and in 24 hours in other inland, near shore, and offshore areas. Using an oil spill slide rule (Ministry of Transport and Public Works, The Netherlands, 1985) it is estimated that in 12 hours this spill would spread to a thickness of 0.14 mm and cover an area with a radius of 0.43 NM (0.8 km) assuming (also from the slide rule) that during the 12 hour period 28% of the spilled product would evaporate. The problem of determining Spill Encounter Rate for a recovery system will now be demonstrated using Figure C-1 to perform the necessary computations.

Assume the operator is to respond to the 2,500 BBL spill with a recovery system that has a Sweep Width of 100 feet (30 m) and a SOA of 0.75 knots. Go into the left section of the chart and at a Sweep Width of 100 feet go up vertically to 0.75 knots. The vertical scale on the left shows that the Sweep Rate is 0.01 NM²/hr. Now move across the graph horizontally to the slick thickness, 0.14 mm, then straight down to see that the Spill Encounter Rate is about 30 BBL/hr. (The computed result is 37 BBL/hr.) For this simple application, this is already the solution to the problem. Recall that we estimated 28% of the oil would evaporate in the 12 hours it would take to respond to the spill, so as the recovery system begins to operate, 2,500 BBL less 28% or 1,800 BBL remain. Since the Spill Encounter Rate is 30 BBL/hr, this system would take about 60 hours to clean up the spill assuming no further evaporation and that the oil does not continue to spread. (These problems are discussed in the paragraph that follows.) If the skimmer can work 10 hours per day it would take about six days for cleanup. If the skimmer can work 8 hours a day, it would take seven and a half days.

Of course, while the response effort is progressing the spill would continue to spread so that the area would be larger than estimated here and the slick would be thinner. The oil would also continue to evaporate, but at a slower rate. In addition, as the recovery system works, the spill may be filling in behind it. (Sweeping with a skimmer system is not like cutting the lawn; an area that is swept out once does not necessarily remain clean because oil is likely to continue to spread or be driven by winds and currents into the area that has been swept out and the work must repeated.) In any case, the computation that was just made provides a numerical approach to the problem and should be a great help in any other judgements that must be made.

As a footnote to this discussion, we realize that the spreading model used in this example is very approximate; however, we feel sure that the reader may use any other spreading model he wishes and the result will show the spill spreading over a broad area requiring a similar level of effort for cleanup.

Now we will use the same sample spill to solve a more detailed problem using the Contingency Planning Work Sheet, Table C-1. The table shows three hypothetical skimmers that have widely varying Sweep Widths and Skimming Speeds. This will also help to illustrate the trade-off in sweeping at a higher speed but with a narrower Sweep Width. We will describe the data entries for the first column and the others will be completed in a similar way.

The boom skimmer shown in the first column has a 100 foot (30 m) Sweep Width and 0.75 knot SOA and, hence, a Sweep Rate of 0.01 NM²/hr, which is the same number that we used as we began the illustration above. The Spill Encounter Rate in a 0.14 mm slick is about 30 BBL/hr (4.8 m³/hr) using Figure C.1. Now record the Area Covered in 4, 8, and 10 hours. This is simply done by multiplying 4), the Sweep Rate, and the work periods. These are sample work periods that can be used to develop a contingency plan. The Oil Volume Recovered in these periods of time is the product of 5), the Spill Encounter Rate (30 BBL/hr), and the proposed work periods. To estimate the Storage Volume Required, assume that the percent oil in the recovered mixture can be measured or estimated. The user will then just divide the Volume of Oil Recovered (row 7) by the percent oil in the recovered mixture to get the storage space required in those periods of time. This number may not be highly accurate but it will be helpful because there are not likely to be any other ways to estimate storage volume requirements.

Row 9) shows the type of pump used. This is probably recorded elsewhere, but it is good to have it on this sheet because it is important to the operation of the system.

Row 10) shows Spill Encounter Rate for a 1 mm slick. As mentioned previously, this number is useful to quickly determine Spill Encounter Rate in any situation simply by multiplying by the existing slick thickness. This value can either be determined by computation or by using the graph. Using the graph, go horizontally across at the Sweep Rate to a slick thickness of 1 mm, then down to read a Spill Encounter Rate of about 250 BBL/hr (this is 266 BBL/hr using a computation).

Row 12), Slick Thickness Corresponding to Maximum Pumping Rate, is the Published Pumping Rate divided by the Spill Encounter rate for a 1 mm slick. This is the maximum thickness the system can handle without exceeding the Published Pumping Rate. The computed slick thickness is 7.5 mm. For a graphical solution, go to the graph at a Spill Encounter Rate of 2,000 BBL/hr then go vertically to the Sweep Rate of 0.01 NM²/hr. This shows that this system could take a slick about 8 mm thick without exceeding the Published Pumping Rate. The pump in this example has a very high capacity; however, in some cases Spill Encounter Rate may exceed Published Pump Capacity, which can cause a problem.

Rows 13) and 14), showing oil viscosity and wave height, provide a space to record characteristics that may influence the effectiveness of the skimmer used. These are filled in so that all the data needed to make performance judgements are in one place. This information helps to estimate percent oil recovered for row 15) if this number cannot be measured.

The other columns on Table C-1 are filled out in a similar manner that will not be described here. Since Figure C-1 does not go below a Sweep Width of 10 feet (3 m), the Sweep Rate for the ZRV rope mop skimmer can be determined in column three by dividing the Sweep Width of 5 feet by 6,076 feet (1 nautical mile) and multiplying by 4 knots. All other numbers are taken from Figure C-1.

The performance summary at the bottom of Table C-1 shows the combined Sweep Rate for the three systems. This could be used to estimate the time required to sweep out the spill area one time if the Area Covered by the spill is known. The next line shows how much area is covered in a standard work day, which is also a measure of how long it will take to sweep through the area once. Next is the total Oil Volume Recovered per day, which can also be used to estimate the time required to cover the spill area. That is, if this combined recovery system could maintain these computed recovery rates, the 1800 BBL (286 m^3) spill remaining after evaporation would be recovered in about 2 days (1800 divided by 850). This, of course, does not account for any additional oil spreading or the requirement to sweep through the spill area several times.

The total Storage Volume Required per work day is shown next. This is simply the sum of the storage volumes for the standard work day shown in Table C-1. Finally, the oil/water separation capacity requirement is shown. The number on Table C-1 is the total recovered product volume less the oil volume, which assumes that only the water phase of the recovered product will be passed through a separator. This would be accomplished by pumping the water from the bottom of the temporary storage tank through the separator to clean it and stopping the separator as it began to draw oil. If the entire recovered product is to be put through the separator, this number would be the same as the total storage volume.

Some other data on the Table C-1 are also of interest. If the brush skimmer is really able to skim at 2 knots with a 66-foot (20 m) Sweep Width it would be a highly effective system. The 2 knot SOA may be optimistic. Table C-1 also shows that the brush skimmer pumping system is just barely adequate for high capacity because it would exceed its Published Pumping Rate in a slick of 1.3 mm. The ZRV rope mop skimmer has a high SOA but a narrow Sweep Width, which reduces its performance. Its pumping rate is also marginal since it would become saturated in a slick of 1.4 mm.

4.0 CONCLUSIONS

This Appendix is intended to provide a format for evaluating advancing skimming systems for contingency plans and operational spill encounters. For contingency planning, the user can establish a simple spill scenario for a specific facility by looking at the kinds of products that could be spilled, the likely size of the spill, and the estimated area the spill would cover. It is then possible to evaluate the system response capability by determining the total Spill Encounter Rate for all available advancing skimmers at the facility. Although the system cannot tell you how long it will take to clean up a spill, it will indicate how long it would take to sweep out the spill area, and this is a good beginning. The system will provide a good measure of effectiveness for available systems and will quickly show the user whether additional systems are needed. Further, if existing systems are inadequate to do the job, the Work Sheet can be used as a procurement decision guide to determine what kinds of recovery systems should be added. It is, for example, very effective in showing the trade-offs between a relatively fast system with a narrow Sweep Width and a slower system with a much broader Sweep Width.

<u>A small number of very high capacity skimmers will provide a high level of response effectiveness only if these advancing systems have high Spill Encounter Rates</u>.

A large, expensive skimmer with a relatively high speed of advance but a narrow Sweep Width may not be the most cost effective alternative. Skimmer effectiveness based on Spill Encounter Rate may show that a larger number of recovery systems, that would together have a much higher Sweep Rate and Spill Encounter Rate, may be a better choice. The performance of high capacity advancing skimmers can never be better than their Spill Encounter Rate, so a high system pumping rate does not always represent a high level of effectiveness.

Finally, Spill Encounter Rate calculations show the value of an early response. As response time and spill volume increase, the spill spreads over larger and larger areas, which will require an ever increasing number of advancing skimmers to clean the oiled surface. The problem can at least partially be solved by rapid response. For recoverable spills, the contingency planner can use Spill Encounter Rate calculations to determine how quickly he must respond in order to be able to effectively cover the spill area with a reasonable number of recovery systems.